DESCRIPTION

"AUTONOMOUS GARMENT WITH ACTIVE THERMAL CONTROL AND POWERED BY SOLAR CELLS"

Related Documents

There are many patents related with this invention. Some documents are associated with heating techniques in garments: WO03059099, EP1197722, US2001047992, DE19835984, US5893991, US5643480, EP0287294, US4705935, FR2577390, US2003006229, and US4404460 that use the thermoelectric effect; FR2752363 mentioning solid and liquid fuels; US6439942 and FR2577116 describing solar arrays; US4539714 utilizes microdendritic solar energy collectors. Other documents are related with cooling procedures in garments: DE19755181 and DE19749436 describe flexible stripes; GB2352385, US6125645, US5289695, and US5111668 include appropriate materials; WO02067707, US6257011, FR2719892, and US5217408 mention forced ventilation by fans; US5438707 uses fans and compressed air; US6134714, US2002073481, US2002069448, FR2756709, US5415222, US5263336, and US3736764 use liquid refrigeration; US5755110 and DE20011331 refer heat exchanging materials; US5386823 describes a ventilated thermal suit. Furthermore, document DE19745889 includes Peltier cells and matrix resistors for cooling/warming

solutions, and US5603648 specifies a safe-vest with accessories.

Field of the invention

This invention is included in the apparel segment, namely in the emerging sector known as intelligent wear (i-wear). It is related with systems and methods for automatic control of temperature in garments, not only for standard weather conditions but also for extreme environments. Furthermore, this invention also refers to special elements that provide power for those vests.

Background

The invention refers to an autonomous garment with active thermal control powered by solar cells that is designed not only for standard conditions but also for extreme weather environments. Hereafter, by "autonomous" we mean there is no need of plug in to a power line, assuring portability and energy autonomy of the garment. Furthermore, by "active thermal control" we mean the ability to produce both heat and cold in the garment and to control dynamically the internal temperature according to external conditions and user needs.

At present time there are several methods to provide temperature control of garments, which can be split

in two different categories: warming and cooling. However, few patents cover both categories simultaneously.

a) Warming garments

In general, warming systems embedded in garments use the thermoelectric effect to provide heat for articles of clothing. An electric current, provided by batteries or power line, is transformed into heat in resistors embedded in garments, mainly in jackets, and in blankets. This technique is claimed in patents WO03059099, EP1197722, US2001047992, DE19835984, US5893991, US5643480, EP0287294, US4705935, FR2577390, US2003006229, and US4404460. Most of the described objects include means to maintain the produced heat, using special fabrics or geometry. Patent FR2752363 refers to a warming system powered by solid and liquid fuels, which feed an engine to produce heat. Patents US6439942 and FR2577116 describe garments heated by means of resistors powered by solar arrays. Patent US4539714 and other references therein claim the utilization of microdendritic solar energy collectors that generate straightforward warming of pieces of clothing.

b) Cooling garments

The cooling garments already claimed have associated different techniques to produce cold: proper

shape, fabrics, and special materials, natural or forced ventilation, cooling fluids or evaporation. Patents DE19755181 and DE19749436 describe a configuration with flexible stripes that allow natural ventilation. Cooling and sweat removal and evaporation by cooling in appropriate materials are described in patents GB2352385, US6125645, US5289695, and US5111668. On the other hand, forced ventilation systems are claimed in patents WO02067707, US6257011, FR2719892, and US5217408, which use small fans powered by batteries or are connected directly to power line. Patent US5438707 uses simultaneously cooling with compressed air and fans. Patents US6134714, US2002073481, US2002069448, FR2756709, US5415222, US5263336, and US3736764 describe systems with refrigeration liquids inside pipes embedded in garments, which permit the cooling by evaporation. Patent US5755110 describes a system that uses a special material to absorb heat, and patent DE20011331 claims the utilization of a textile fibre with special properties for storing and releasing available heat, depending on the needs. Finally, patent US5386823 is related with a ventilated suit with mask that is connected to a cooling device with low portability.

c) Garments with both warming and cooling systems

Although there are many patents and other documents related with cooling and heating systems and methods, to our own knowledge only one uses both techniques in the same

garment: patent DE19745889 illustrates garments with Peltier elements for cooling and matrix resistors for heating that are connected to an electricity source, namely power line, friction wheel, propeller driven generator or batteries.

d) Other applications

The major number of documents refers to heat or cold generation but some garments include accessories for other applications. Patent US5603648 describes a safe-vest with several accessories, namely optical fibres and LEDs powered by solar cells, resistors powered by batteries to provide heat, and other signalling and survival gadgets. This solution is especially useful in rescue missions and other risky assignments.

e) Power autonomy

Most autonomous systems available on the market generate either heat or cold, and do not have both solutions embedded in the same garment. The large majority of the systems must be connected continuously to the power line even though some smaller articles of clothing include batteries to provide some energy autonomy. Thus, systems connected to power lines are neither portable nor autonomous, and solutions with batteries have low autonomy. Therefore, autonomous pieces of clothing need large and heavy batteries

or must utilize very low power, preventing the addition of thermal control units, mainly cooling solutions, where the thermal cycle efficiency is lower.

Some small pieces of clothing use solar cells or energy collectors to provide power to feed resistors, which are used to warm articles of clothing.

f) Temperature automatic control

There are several methods to control the temperature inside garments but almost all of them use a passive approach. The most common solutions release heat or cool continuously, such as fans, even though some methods include mechanisms to control heating and cooling fluxes, like orientation of flexible stripes. Nevertheless, more effective methods utilize thermostats to regulate temperature, switching thermal devices on and off to control heating or cooling flows. So far, these control units do not require sophisticated algorithms because they are only used to turn a thermal source on or off. However, the development of systems with active thermal control allows a more efficient management of heat and cold inside garments.

g) Conclusion

Presently there are many solutions and methods to include heat or cold production in garments, which is evident due to the large number of patents and other published documents. However, these solutions have in common several limitations.

The most important constraint in garments with thermal control is related with power generation, because either the systems generate significant amount of power but are not portable, or they are autonomous but the power generated is rather small.

The large majority of available systems include either cooling or warming units but do not provide both solutions in the same piece of clothing, mainly due to power limitations.

The inclusion of both cooling and warming devices in the garment requires a much more efficient management of thermal control.

All the systems and methods claimed so far do not provide simultaneously the following characteristics: power autonomy, automatic control of temperature, cooling and heating cycles, and portability.

Summary of the invention

The present invention reduces limitations both in portability and autonomy, and allows warming and cooling thermal cycles in the same piece of clothing. One of the main goals of this invention is to solve these limitations without a significant increase in weight. Furthermore, it fore sees a more efficient way to manage temperature distribution and power resources.

A standard application in garments includes the following units: solar cells, batteries, cooling device, warming device, active thermal controller, wiring grid, and auxiliary gadgets.

Solar cells are assembled in a flexible substrate and can include special filters or optical parts. Solar cells use flexible substrates made of inexpensive silicon beads sandwiched between two thin layers of metal foil embedded in a plastic cover. The metallic sheets give the material physical strength and act as electrical contacts. Furthermore, the wavelength that provides maximum optical-to-electric energy efficiency can be shifted to match different radiation sources. Thus, not only solar radiation but also from other sources can be used, namely fluorescent lamps and flames.

The utilization of batteries in the garment is convenient not only to store energy but also to provide power stabilization, namely when power transients occur in the solar cells. New technologies allow the development of ultra-thin flexible batteries, and their series and parallel association increase the power storage to more that 200Wh/kg. Moreover, thin batteries are easily shaped so that weight distribution in the garment is possible and substrate flexibility allows ergonomic profiles.

The devices utilized to produce cooling use different techniques. Peltier cells are made from two dissimilar metals and the application of a DC voltage to a closed circuit gives rise to a temperature change at the junction of the two metals. Peltier cells do not have moving parts, are lightweight, and can be used in any orientation. Furthermore, they may be stacked to achieve greater temperature differential. Miniaturized compressed cooling machines with coefficient of performance (COP) ~4 are available. Thus, vapor compression cycles are very efficient systems providing a cooling process to garments. Additionally, the utilization of thin flexible pipes allows a proper distribution of thermal flow across the piece of clothing.

The most effective method to provide heat to the garment is the conversion of electrical energy in heat by

means of resistors. Wiring, high flexibility, and weightless of electrical resistors make them the more suitable elements to generate heat inside the garment.

The proper thermal control in the garment is better obtained with active units, mainly because on/off systems are not effective in complex systems that use both cooling and heating cycles. On the other hand, the active thermal control proposed in this document uses not only parameters from those cycles but also from human body activity, external environment, and preset conditions. Thus, thermal control units can use sophisticated algorithms.

Wiring is an important issue for assembling procedures. Although solar cells, batteries, resistors, and pipes have high flexibility it is fundamental to study stress and fatigue in some of the junctions of the garment, namely those related with the human articulations.

As there is some power available in the garments, they can include auxiliary plugs to feed external devices, namely laptops, mobile phones, audio readers, and other low power electronic devices.

Detailed description of the invention

The presented invention refers to an autonomous garment with active thermal control and powered by solar cells.

Fig.1 represents a piece of clothing that includes several units for powering, warming, cooling, and controlling the whole system.

Fig.2 shows, as an example, a clothing uniform with the illustration of solar cells on the surface.

In a simple configuration, the system includes one or several pieces of clothing, solar cells (1), batteries (2), resistor circuits (3), refrigeration units (4), and an automatic thermal controller (6). Alternatively or together with the resistors and cooling units use Peltier cells (5), which can be used for heating and cooling. As Peltier cells are able to produce or remove heat in the same unit just by changing the current direction on the cell, garment versatility can be increased. The solar cells convert electromagnetic radiation in electric power, which is used to feed the electric devices. The distribution of resistors and refrigerating pipes (7) is adjusted according to human body needs, in order to produce or remove heat in the garment. The thermal unit assures that temperature inside the garment is

maintained in the selected range, which can be function of metabolic activity, weather conditions, breathable fabrics properties, and pre-selected values defined by the user. Furthermore, a specific algorithm surveys the thermal control unit and manages heating and cooling production in the garment. The batteries have two different purposes in the system. On one hand, they are used to stabilize power consumption if there is a strong variation in the electric power production. On the other hand, the batteries are used to store energy and provide extra power to increase autonomy, namely when radiation level is low or no longer available.

a) Solar cells

The solar cells absorb radiation and convert it in electricity, which is supplied to the devices under control. The generated power can also be stored in the batteries. The solar cells are the outer active layer of the garment, must be flexible, and have to have low bending stress with time. Moreover, solar cells shall have good wiring properties.

Solar cells have to be covered with an optical external layer to prevent weathering degradation. This layer shall be thin, flexible, and transparent to visible radiation.

The global power efficiency of the solar cells shall be higher than 10%, in order to provide enough energy to the thermal units. This value is the state-of-the-art efficiency for flexible solar cells.

Solar cells cover as much as possible of the outer layer of the garment to maximize available area. However, special human articulations, such as shoulder, elbow, and knee, can damage solar cells so that high bending joints in the garment shall not be covered with solar cells. Special wiring is used to interconnect solar cells in an overall grid and the electric bus connector that provides power distribution and signal control to all devices.

b) Batteries

Batteries store energy supplied by the solar cells or a power line. The main functions for batteries are energy storage and power stabilization.

The batteries must be thin, lightweight, flexible, rechargeable, and must have low bending stress with time. The state-of-the-art flexible batteries allow up to 200Wh/kg, which allow autonomy of 3 hours for minimum warming and cooling thermal requirements. The batteries layer is embedded in the garment and has the same bending constraints as the solar cells. Batteries are connected to the electric bus

connector that provides power distribution and signal control to all devices.

c) Warming cycles

The garment has two different systems to provide heat. The utilization of resistors is the most efficient method to warm articles of clothing. The second system includes Peltier cells.

Resistors must be thin, flexible, and lightweight. Furthermore, they must have low bending stress with time and good wiring connectors. The wiring grid and resistors distribution in the garment are selected to provide appropriate heat flow inside the garment. Furthermore, several sectors of resistors can provide heat independently of each other, which allow unbalanced distribution of energy if required. For example, this technique allows differentiating energy distribution in chest, arms, and legs. Resistors layers are embedded in the garment and can also be impregnated directly in fabrics.

Peltier cells are used both for warming and cooling purposes and are also embedded in the garment. This property makes them useful for areas of the garment that are subject to high thermal inertia. However, as they are heavier than resistors, Peltier cells are properly distributed to balance weight in the piece of clothing.

Resistors and Peltier cells are connected to the electric bus connector that provides power distribution and signal control to all devices.

d) Cooling cycles

The utilization of miniaturized cooling cycles with high COP is a proper solution to provide a cooling system to the garment. The utilization of thin flexible pipes permits an efficient distribution of temperature inside the garment. The utilization of different tube diameters and pipe distribution allocates unbalanced cool distribution, using different fluid flow and valves in the pipes.

The cooling cycle systems are connected to the electric bus connector that provides power distribution and signal control to all devices.

e) Temperature controller

Simple thermostat devices used so far to control temperature in garments are useful but inefficient for more advanced systems because a simple on/off control type is inappropriate. Thus, a programmable microcontroller is used. The management of temperature includes several important inputs such as sensors signals, user defined settings,

feedback conditions, and device performance monitoring values.

The utilization of temperature sensors (e.g. thermocouples) monitoring garment temperature, external environment conditions, and body temperature of the user provides useful information.

A model describing production and distribution of heat flow on the human body is included. The heat flow level is function of physiological parameters, e.g. body activity, and weather conditions.

A special algorithm is developed to process all information related with sensors, devices status, body activity model, weather parameters, and preset conditions. The algorithm is run in the microcontroller unit surveying and analysing temperatures within the garment, controlling heat and cool production, and preserving thermal preset comfort conditions. The microcontroller is connected to the electric bus connector that provides power distribution and signal to control the garment, managing all devices and accessories.

f) Other applications

The power generated in the garment can be used for other purposes, in particular to provide energy to small appliances like laptops, audio readers, positioning systems, mobile phones, digital cameras, signalling and warning devices. The small appliances are connected to the electric bus connector that provides power distribution all devices.

g) Conclusion

This invention is unique in the following characteristics:

1. Includes both warming and cooling cycles in the garment, and provides the automatic thermal control.

2. Solar cells are used to power both cooling and heating units.

3. The garment can use other spectral sources than solar energy, namely optical radiation of fires..

All the claimed systems so far do not provide simultaneously the following characteristics: power autonomy, automatic control of temperature, cooling and heating cycles, and portability. The cooling garments currently available do not use solar cells to provide power to the system. The two available systems that include solar cells for heating purposes claim to utilize solar radiation only. All the solutions that provide temperature control at the present

time use either warming or cooling devices, but do not include both solutions in the same piece of clothing.

This invention, which simultaneously provides warming and cooling active thermal control, can be applied in a wide range of weather conditions and included in different clothing types, namely jackets and uniforms (Fig. 1 and Fig. 2). The system can also work without solar radiation if another radiation source is present, namely artificial illumination (e.g. lamps). A particular useful situation is provided by fire radiation, which can be converted in electricity and used to cool fireman suits.

Pieces of clothing can include sensors monitoring the external weather conditions, communications and positioning devices, and luminous and sonorous signalling apparatus. These types of sensors and gadgets are particularly important in extreme conditions and sparsely inhabited areas, namely deserts, Polar Regions, and mountains.

An additional application of this invention is related with the utilization of solar cells to provide energy to small portable electronic devices such as laptops, mobile phones, and audio players.